DISCOVERY

Review of cases of diarrhea among infants in Africa: Causative organisms, detection methods and infant age distribution

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ABSTRACT

Diarrhoea is one of the most common health problems in Africa. This faecal-orally transmitted disease is responsible for the death of 1.9 million children under five years with a high proportion from resource-poor nations. The objective of this study is to review existing articles on the incidence of diarrhoea among infants in Africa. In this study different databases which include PubMed, Google Scholar and CrossRef were searched for articles published in Africa and the year range between 2000 to 2020. The study design included the population involved (in the hospital and community) and the results were reviewed. In this study, a total of 234,568 subjects were out of which 57,222 were positive. Infants with the age range from 25 to 60 months were diagnosed in this study while the least number was within the age group of 13-24 months. The sex distribution of the children diagnosed with diarrhoea was very close. A total of diagnosed children reported were from Nigeria (n = 32,443 (56.7%)), followed by Kenya with 6,110 infected children. The last occurrence was reported in Namibia with 35 cases. Data from the hospital had the highest occurrence. Among the causative agents detected, viruses had the highest occurrence followed by protozoa. Polymerase Chain Reaction (PCR) followed by cultural methods were the two main methods used in the diagnosis of the infection. This study shows the incidence rate and occurrence of infantile in African countries, the causative agents responsible for diarrhoea among infants and their respective distribution.

Keywords: Diarrhoea, infants, faecal-oral, enteropathogen, children

1. INTRODUCTION

Diarrhoea may be a major explanation for childhood morbidity and mortality in socioeconomically developing countries. Quite one billion episodes of diarrhoea occur per annum among children under five years of age causing approximately 2.5 million deaths (Kosek, 2003). The World Health Organization (WHO) Child Health Epidemiology Group estimates that 16% of deaths in African children

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younger than five years are directly due to diarrheal diseases (Bryce et al., 2005). The aetiological agent of diarrhoea among infants comprises of various types of enteropathogens ranging from viruses to parasites. For several Sub-Saharan countries, studies on the prevalence and clinical significance of various diarrheal pathogens aren't complete. Meteorologic, geographic and socioeconomic factors have been reported to considerably affects the distribution of etiological agents of diarrhoea, while poor personal and environmental hygiene, lack of access to quality and adequate water supply and lack of education of health personnel among other related factors (Curtis, 2000; Thapar, 2004).

Diarrheal infection is the most frequent childhood illness and a standard explanation for hospitalization in developing countries. Despite the substantial reduction in child mortality between 2000 and 2010, globally, acute diarrhoea remains the second leading explanation for death among children under 5 years old. It is estimated that globally 800,000 children under the age of 5 years die annually, mostly in Sub-Saharan Africa and South Asia (Kotloff et al., 2013). In Sub-Saharan Africa, including Kenya, urban migration has increased, leading to the rapid expansion of cities. This has led to the creation of overcrowding in urban slums, low socioeconomic conditions, poverty, illiteracy, poor sanitation and malnutrition, which all raise the speed of infectious diseases including diarrhoea.

According to WHO, diarrhoea is described as the passage of unformed and/or semi-formed stool within 24 hours for at least three times. The etiological agents for acute diarrhoea include a good range of viruses, bacteria and parasites: however, causative agents differ considerably between developed and developing countries (WHO, 2017). The occurrence of diarrhoea in resource-poor nations is usually high during the winter with viruses being the most frequently encountered pathogens. Within the developing world, diarrhoea remains a seasonal disease, with bacteria playing a greater role (Mackenjee et al., 2003). However, rotavirus has been found as one dominant enteric pathogen among children in most developed and developing countries (Parashar, 2006).

More than half of under-five child deaths are due to diseases that are easily preventable and treatable through simple, cost-effective and affordable interventions. Strengthening health systems to supply such interventions to all or any children will potentially save many young lives (WHO, 2017). In 2015, the United Nations adopted the Sustainable Development Goals (SDGs) to scale back child mortality and to market well-being for all children (WHO, 2017). Despite interventions and innovations by a variety of stakeholders, under-five mortality associated with diarrhoea remains a serious concern, especially in developing countries within the African continent. In recent years, several studies are conducted to estimate the prevalence and also to identify modifiable factors of under-five diarrheal diseases (Page et al., 2011; Dairo et al., 2017; Mchaile et al., 2017; Muendo et al., 2018).

More than two dozen enteric pathogens, belonging to diverse branches of the tree of life, are known to cause diarrhoea and can be tested for in a clinical setting. However, additional pathogens likely remain to be identified among the enteric micro biota (Kotloff et al., 2013). Several groups of viruses are shown to be responsible for acute diarrhoea among infants within their first few months after birth (Giordano et al., 2001). Rotavirus ranked first among etiological agents of severe dehydrating infantile diarrhoea. It has responsible for more than 100 million cases with case fatality of 440,000 annually (Parashar, 2006). Rotaviruses are members of the Reoviridae family and possess a genome that consists of 11 segmented double-stranded RNA genes that code for both structural and non-structural proteins. They need a triple-layered structure consisting of a core encapsulating the segmented RNA genome, an inner capsid which bears group-determinant antigens and an outer capsid formed by two proteins involved in virus neutralization and protective immunity and whose antigenic characteristics have determined their serotype specificity (Estes and Kapikian, 2001).

Enterotoxigenic Escherichia coli, Salmonella paratyphi, Shigella species and Campylobacter species appear to be the most etiological agents but certain circumstances are associated with an especially high incidence of acute diarrheal disease. Escherichia coli is considered to be the etiological agent of many diseases, including some affecting the urinary tract and intestine. The classification of diarrheagenic Escherichia coli (DEC) strains is based on their virulence properties and comprises six groups: enterotoxigenic Escherichia coli (ETEC), enteropathogenic Escherichia coli (EPEC), enteroinvasive Escherichia coli (EIEC), enterohaemorrhagic Escherichia coli (EHEC), enteroaggregative Escherichia coli (EAggEC) and diffuse Adhering Escherichia coli (DAEC) (Nataro and Kaper, 1998). Intestinal infections are caused by the pathovars; EPEC, ETEC, EIEC, EHEC and EAggEC. EPEC and EAggEC frequently cause diarrhoea in infants. ETEC produces enterotoxins that cause a cholera-like clinical picture. EIEC cause a dysentery-like infection of the large intestine. EHEC produce verocytotoxins and cause hemorrhagic colitis as well as a rare hemolytic-uremic syndrome. E. coli bacterial infections are diagnosed using pathogen identification (Braz et al., 2020; Geurtsen et al., 2022).

Campylobacter species are small Gram-negative, non-spore-forming, helical bacteria with a particular 'darting' motility and are catalase and oxidase positive. *Campylobacte* species are often found within the reproductive organs, intestinal tracts and mouth mouths of animals and humans (Kassu et al., 2000). Among *Campylobacter* species, the most ordinarily isolated species from cases of

gastroenteritis were *Campylobacter jejuni* (*C. jejuni*) followed by other *Campylobacter* species. In Africa, a couple of studies have indicated that campylobacteriosis is commonest among children of young age. In Ile-Ife, Nigeria, *C. jejuni* was found to be a crucial agent of diarrhoea in children (Aboderin et al., 2002). In Durban, South Africa, *Campylobacter* was found in 21% of diarrheal cases among children aged five years (Mackenjee et al., 2003).

Shigellosis is one of the most public health problems throughout the planet. *Shigella* sp. has been reported as one of the foremost causative agents of dirrhoea among children in developing countries. Rotavirus, *Cryptosporidium* and enterotoxigenic *Escherichia coli*—ST-ETEC have been reported to cause moderate to severe cases of diarrhoea among infants in Sub-Saharan Africa (Kotloff et al., 2013). Unlike viral and bacterial agents of diarrhoea, parasites that cause infantile dirrhoea are not given much attention. *Cryptosporidium* species, *Isospora belli*, *Microsporidia* species, *Giardia intestinalis*, *Entamoeba* species, *Cyclospora* species, pose unique epidemiological constraints as they are ubiquitous, resistant to chemical agents used in the treatment of water and other antiseptics (Mariam et al., 2008). The World Health Organization (WHO) reports that the foremost common diarrhoea-causing protozoan parasite worldwide is *Cryptosporidium* and a recent, large, multi-country investigation reported that *Cryptosporidium* because the second commonest pathogen identified among care-seeking African and Asian infants 0 to 11months. Despite these indications of the potential global scope and impact of cryptosporidial infection, epidemiology of the infection is not clearly understood like other agents (Kotloff et al., 2013).

Giardia lamblia is an enteric parasite that causes giardiasis, one of the frequent causes of diarrhoea, in humans, pets and livestock (Thompson, 2000). The parasite is distributed globally and youngsters are more in danger of infection than adults (Mohammed et al., 2008; Addy, 2004; Dib, 2008; Noor et al., 1984). It is one of the intestinal protozoa that cause public health problems in most developing countries. Several studies have associated these infections with socio-demography, hygiene, nutritional and immune status of the host and strain of the parasite (Thompson, 2000; Mohammed et al., 2008; Sackey et al., 2003). *Giardia lamblia* has 6 distinct genotypes; assemblages A and B are found in humans and other mammals, C/D in dogs, E in livestock, F in cats and G in rats (Amar et al., 2002; Sulaiman et al., 2003). Molecular methods could be very useful in detecting the presence of *G. lamblia* in stool samples of infants with the severity of diarrhea.

Diarrhoea results due to the spread of infectious organisms and the organisms are transmitted through the faecal-oral route mode. Faecal pathogens are primarily transmitted through the faecal–oral pathway while fluids, fields/floors, foods and flies serve as reservoir and/or vector (Curtis et al., 2000). This work reviewed the occurrence of diarrhoea among under-five aged children in Africa using the existing data.

2. METHODOLOGY

Search Criteria

The systematic review search for publications on Diarrhea among infants in African countries was done in March 2022. The period included for this search was from the year 2000 to 2021. The literature search was done using PubMed website, google scholar and CrossRef to identify all published papers reporting “Diarrhea among infants in Africa”, “incidence of diarrhoea among under-five aged children in Africa”, and "prevalence diarrhoea among infants in Africa". Published articles were from Burkina Faso, Egypt, Ethiopia, Ghana, Guinea Bissau, Kenya, Madagascar, Malawi, Morocco, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Zambia and Zimbabwe. Duplicated articles were excluded from this study. Additional publications were obtained from the references and were selected if the following criteria were fulfilled: Availability of full-text articles in English, the study area must be within Africa and the year must be between the years 2000 to 2021. This study design includes the population base (community and hospital) and the results reviewed as also the age group infected. The flow diagram of studies included in review is shown in Figure 1.

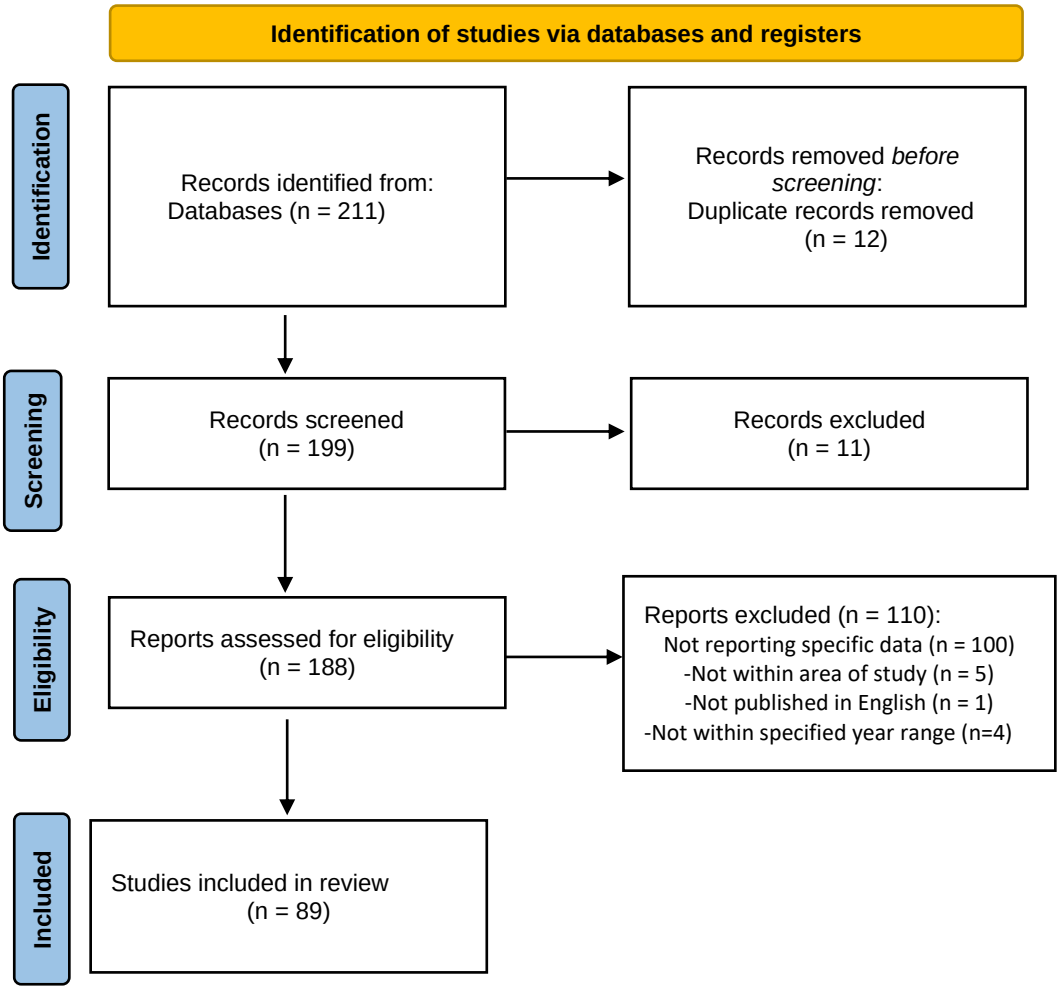

Figure 1 Flow diagram of studies included in review—cases of diarrhea among infants in Africa

Eligibility of Study

Articles available with full text in English, studies on diarrhoea among infants in Africa with the year ranging from 2000 to 2021 were eligible for this study. Articles in which the study area is within Africa and with relevant data were also eligible for this study.

Inclusion Criteria

The articles that the study area is not within Africa, not within the year range (2000 to 2021), not written in English, not have relevant data needed and with no citations were excluded.

3. RESULTS

Table 1 showed the percentage distribution according to the age groups of screened participants. The age range of the participant included in this study is between 0 to 60 months. The age group predominantly included in the articles reviewed was 25 to 60 months (37.46%), followed by the infant population i.e., 0 to 12 months (19.65%). The lowest recorded was from the age group 13 to 24 months (13.47%). Table 2 showed the incidence of diarrhoea according to gender and country distribution. The total screened (234,568) and total positive (57,222) for diarrhoea segregated by Gender were presented. Although Uganda and Tunisia were not stated.

Table 1 Age distribution of children with diarrhea in the studies

Age (Months)	Total Screened	Percentage (%)
0-12	46,088	19.65
13-24	31,601	13.47
25-60	87,871	37.46
NS*	69,008	29.4
TOTAL	234,568	100

NS= Not specified

Table 2 Incidence of diarrhea among the subjects by gender

Countries	Gender	Total screened	Total positive	Incidence/1000
Burkina Faso	M = NS F = NS	343	262	763.8
Egypt	M = 2,295 F = 2,163	4,458	1,129	253.2
Ethiopia	M = 32,289 F = 30,797 NS = 4,845	67931	3,298	48.5
Ghana	M = 170 F = 104 NS = 347	621	1,102	1,774.6
Guinea Bissau	M = 204 F = 211	415	93	224.1
Kenya	M = 6,567 F = 8,488 NS = 16,397	31,452	6,110	194.3
Madagascar	NS = 3,424	3,424	127	37.1
Malawi	NS	241	45	186.7
Morocco	NS	1,861	535	287.5
Namibia	M = 273 F = 293	566	35	61.8
Niger	NS	6,621	2680	404.8
Nigeria	M = 9,218 F = 8,979 NS = 26,721	44,915	32,443	722.3
Rwanda	M = 3,766 F = 3,708	7,474	93	12.4
Senegal	NS	321	47	146.4
South Africa	M = 136 F = 146 NS = 9,886	10,168	2,603	255.9
Sudan	M = 11,690 F = 11,600 NS = 766	24,056	1,713	71.2
Tanzania	M = 739 F = 529 NS = 8,978	10,243	1,532	149.6
Tunisia	NS	NS	180	-
Uganda	Ns	NS	583	-
Zambia	M = 4,946	12,630	1,228	96.9

	F = 5,335 NS = 2,329			
Zimbabwe	NS	6,825	1,387	203.2

Table 3 showed the distribution of the infection according to the country with the total number of articles selected and their respective Incidence per 1000. A total number of 234,568 were sampled and 57,222 (33.4%) infants were found to be positive for diarrhoea. The population distribution of infant diarrhoea concerning the articles selected is presented in Table 4. Reports were majorly gathered from the hospital followed by rural, urban area and country respectively. A total of 234,568 were investigated and a total of 57,222 were reported positive for diarrhoea (Table 4).

Table 3 Incidence of diarrhea among the subjects in the data reported from different countries

Countries	Number of Articles	Number diagnosed	Number infected	Incidence/1000
Burkina Faso	2	343	262	763.8
Egypt	1	4,458	1,129	253.2
Ethiopia	27	67,931	3,298	48.5
Ghana	5	621	1,102	1,774.6
Guinea Bissau	1	415	93	224.1
Kenya	14	31,452	6,110	194.3
Madagascar	1	3424	127	37.1
Malawi	1	241	45	186.7
Morocco	1	1,861	535	287.5
Namibia	1	566	35	61.8
Niger	2	6,621	2,680	404.8
Nigeria	6	44,915	32,443	722.3
Rwanda	1	7,474	93	12.4
Senegal	1	321	47	146.4
South Africa	2	10,168	2,603	255.9
Sudan	3	24,056	1,713	71.2
Tanzania	8	10,243	1,532	149.6
Tunisia	1	NS	180	-
Uganda	3	NS	583	-
Zambia	6	12,630	1,225	96.9
Zimbabwe	2	6,825	1,387	203.2
Total	89	234,568	57,222	5,893.7

Table 4 Population distribution of diarrhea among infants in Africa

Population involved	Number of Articles	Number diagnosed	Number infected	Incidence/1000
Rural	21	43,158	7,894	182.9
Urban	10	10,571	963	91.1
Hospital	42	80,128	41,709	520.5
Not Specified	16	100,711	6,656	66.1
Total	89	234,568	57,222	860.6

The causative organism of diarrhoea across the countries was presented in Table 5. Rotavirus a viral agent recorded 26.3% as the highest causative organism of diarrhoea followed by Enteropathogens (15.8%), Cryptosporidium species (11.8%), Giardia lamblia (9.2%), Entamoeba histolytica and Shigella species (6.6%), Campylobacter species (5.3%) and Salmonella species (4.5%), Ascaris limbroicoidescholera, Norovirus, Astrovirus and Adenovirus all recorded (2.6%) with Sapovirus, Vibrio cholerae, Clostridium difficile representing 1.3% of the estimated number of occurrence from the study. Adenovirus, sapovirus and astrovirus infections accounted for 12.9% of diarrhoeal symptoms in paediatric outpatients. Table 6 presented the detection method used for the identification of microorganisms responsible for the infection. The Polymerase Chain Reaction (PCR) with 22% of occurrence

represents the main method used by scientists for identification followed by cultural analysis (16%), Enzyme-Linked Immunosorbent Assay (ELISA) (13%) and microscopy (10%). Other methods such as Toxin Assay, Rotalex Reagent, Intestinal Inflammation Assessment, RNA Extraction and DNA Extraction all have a 1% appearance each from this study. The map of Africa showing the countries where the reports emanated from is shown in Figure 2.

Table 5 Distribution of causative organism across countries

Causative Organism	Occurrence	Percentage of Occurrence
Viruses		
Adenovirus	2	2.6
Astrovirus	2	2.6
Human Sapovirus	1	1.3
Norovirus	2	2.6
Rotavirus	20	26.3
Bacteria		
Shigella species	5	6.6
Salmonella species	3	3.9
Campylobacter species	4	5.3
Vibrio cholerae	1	1.3
Clostridium difficle	1	1.3
Protozoa		
Cryptosporidium species	9	11.8
Entamoeba histolytica	5	6.6
Giardia lamblia	7	9.2
Ascaris lumbroicoides	2	2.6
Enteropathogens	12	15.8
Total	76	100

Table 6 Detection method used for identification of organisms

Detection Method	Appearance
Enzyme Linked Immunosorbent Assay (ELISA)	13
Culture	16
Microscopy	10
Polymerase Chain Reaction (PCR)	22
Intestinal Inflammation Assessment	1
Rotalex Reagent	1
Nucleic Acid Extraction (DNA)	1
Nucleic Acid Extraction (RNA)	1
Toxin Assay	1

Figure 2 A map showing the countries from which the data were collected.

4. DISCUSSION

People who generally reside in rural or underdeveloped areas are more prone to the ingestion of infective parasites in relation to those who live in urban/suburban or well-developed areas where sanitation is presumably better; hence possess a lower chance of infection. The water supply in urban areas is cleaner, which reduces the chance of contamination. Conversely, activities in the rural areas compel young people and children to have close contact with contaminated soil and water. This invariably increases the chance of ingesting as well as the penetration of infective stage of the parasites (Adjei et al., 2004).

In this systematic review, the distribution of participants according to age group was assessed with 0 to 12 months (19.65%), 13 to 24 months (13.47%), 25 to 60 months (37.46%) and the category of people whose age was not stated accounted for 29.42% of the total subjects. The infection among the age group within 0 to 12 months could be due to crawling on the ground or walking which increases the probability of getting into contact with filth materials that may expose them to pathogenic microorganisms as reported by Azage et al., (2016). This study shows the distribution of infants infected with diarrhoea according to African countries with Nigeria having the highest number of infected infants (32,443), followed by Kenya (6,110), Ethiopia (3,298), Niger (2,680), South Africa (2,603), Sudan (1,713), Tanzania (1,532), Zimbabwe (1,387), Zambia (1,225), Egypt (1,129), Ghana (1,102), Uganda (583), Morocco (535), Burkina Faso (262), Tunisia (180), Guinea Bissau and Rwanda (93), Senegal (47), Malawi (45) with Namibia (35) having the least number of diarrheal incidence. This result is associated with intermittent water supplies that transmit water borne pathogens and increased water storage time jeopardize practices. Poor handling of drinking water is significantly increasing the risk of contracting diarrhoea by infants.

Aside from mixed infection caused by two or more enteropathogens (rotavirus, Escherichia coli, Shigella species, Salmonella species, Giardia species, Cryptosporidium species, Campylobacter species, etc) which represents 53.7% distribution of causative organisms across Africa countries, Rotavirus is the single etiological agent responsible for infant diarrhoea with the highest number of occurrence(14.9%) while Adenovirus, Sapovirus, *Giardia* species, *Entamoeba histolytica* (Parashar, 2006; Dbaibo et al., 2013; Ghssein et al., 2018; Stuempfig and Seroy, 2018). The peak infection age range with rotavirus is 3–24 months, with the highest rate being between the ages of 6–11 months. The study of diarrhoea among infants in African countries reveals that Sub-Saharan African

countries have the highest incidence rate of diarrhoea among infants which can be related to poor sanitation, inadequate breastfeeding, overcrowding, poor waste handling, open defecation, malnutrition, etc. (Youssef et al., 2000; Ismaeel et al., 2002; Hegazi et al., 2013; Naous et al., 2013; Biscaro et al., 2018).

Recent studies have suggested that training public sector providers to treat diarrhoea in children with low osmolarity ORS and zinc is effective in improving the quality of care (Cesar et al., 2000; Fischer et al., 2015). Adequate supply of potable water and information with sensitization will go a long way to reduce the incidence of diarrhoea among infants. Well trained health workers and well-equipped health care facilities at least primary level and at a short distance to parents has also been reported to aid the control of diarrhoea. Availability of Oral Rehydration Salts and zinc in every health care facility in the rural areas is very important. Parents education on how to prepare the solution at home is very paramount to saving the life of infected child (David et al., 2010; Kotloff et al., 2013; Adefarakan et al., 2014; Anyorikeya et al., 2016).

Although appropriate treatment of diarrhoea is simple and can be done at home, seeking care from appropriate providers outside the home is recommended because harmful practices based on beliefs and misconceptions are prevalent, especially in low-income countries where diarrhoea mortality is high. This study reveals that diarrhoea is still a major public health problem in Sub-Saharan Africa resulting in high levels of morbidity and mortality of infants (Cesar et al., 2000; Anyorikeya et al., 2016). These findings confirmed that poor sanitary practices, overcrowding, open defecation, inadequate breastfeeding, malnutrition, etc are strongly associated with infant diarrhoea morbidity.

5. CONCLUSION

Diarrhoea has found a way to continue affecting the infant population which is perhaps due to crawling and walking on the contaminated floor. From this study, infant diarrhoea is caused mainly by rotavirus and other entropathogens which is transmitted via the faecal-oral route. Hence necessary measures such as adequate breastfeeding for the first 6 months of life, proper water and food storage, vaccination against the pathogen where possible, proper waste disposal system and adequate feeding habits should be taken to interrupt this transmission.

Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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